D-branes of Covariant AdS Superstrings [a]
– An Overview –

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ABSTRACT

We briefly review a covariant analysis of D-branes of type IIB superstring on the $AdS_5 \times S^5$ background from the κ-invariance of the Green-Schwarz string action. The possible configurations of D-branes preserving half of supersymmetries are classified in both cases of $AdS_5 \times S^5$ and the pp-wave background.

1. Introduction

D-brane is an important key ingredient in studies of non-perturbative aspects of superstring theories, and it is a recent interest to study D-branes on curved backgrounds. In particular, those on pp-wave backgrounds [1] have been well studied, since the Green-Schwarz strings on pp-waves are exactly solvable in light-cone gauge [2] and so one can study them directly by quantizing the theories [3,4,5,6].

Covariant studies of D-branes in type IIB and IIA strings on pp-waves were discussed in [7] and [8], respectively, by following the method of Lambert and West [9]. Motivated by these developments, we have carried out a covariant analysis of D-branes of type IIB string on the $AdS_5 \times S^5$ background [10,11], by using the Green-Schwarz action obtained by Metsaev and Tseytlin [12]. The possible 1/2 supersymmetric (SUSY) D-brane configurations have been classified. This result is consistent to that of brane probe analysis in [5]. In addition, Penrose limits [13,14,15] of D-branes on the $AdS_5 \times S^5$ give possible D-brane configurations in the type IIB pp-wave background.

On the other hand, by employing the methods of [16], the covariant analysis is also applicable to open supermembranes on the pp-wave [17,18] and $AdS_{4/7} \times S^{7/4}$ [19,20] backgrounds. These results are related via Penrose limit and are also consistent to the brane probe analysis in eleven dimensions [21].

We will briefly review the classification of D-branes on the $AdS_5 \times S^5$ preserving half of supersymmetries, and discuss the Penrose limit of them.

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2. The action of type IIB string on the AdS$_5\times$S^5

First of all, the action of AdS string we consider is written as [12]

$$S = \int d^2\sigma \left[\mathcal{L}_{\rm NG} + \mathcal{L}_{\rm WZ}\right]\,, \quad \mathcal{L}_{\rm NG} = -\sqrt{-g(X,\theta)}\,. \tag{1}$$

The Nambu-Goto part of this Lagrangian is represented in terms of the induced metric g_{ij}, which is given by (For notation and convention, see [10])

$$g_{ij} = E_i^M E_j^N G_{MN} = E_i^A E_j^B \eta_{AB}\,, \quad g = \det g_{ij}, \quad E_i^A = \partial_i Z^{\hat{M}} E_{\hat{M}}^A\,, \tag{2}$$

where $Z^{\hat{M}} = (X^M, \theta^{\bar{\alpha}})$ and $E_{\hat{M}}^A$ are supervielbeins of the AdS$_5\times$S^5 background. For D-strings, g is replaced with $\det(g_{ij} + \mathcal{F}_{ij})$ where $\mathcal{F}$ is defined by $\mathcal{F} = dA - B$ with the Born-Infeld $U(1)$ gauge field A and the pull-back of the NS-NS two-form B. The Wess-Zumino term, which is needed for the κ-invariance and makes the theory consistent, is

$$\mathcal{L}_{\rm WZ} = -2i\int_0^1 dt\, \widehat{E}^A \bar{\theta}\Gamma_A \sigma \widehat{E}\,, \tag{3}$$

where $\widehat{E}^A \equiv E^A(t\theta)$ and $\widehat{E}^\alpha \equiv E^\alpha(t\theta)$. When we consider a fundamental string (F-string), the matrix σ is given by σ_3 . If we consider a D-string, then σ is represented by σ_1 . Since we would like to discuss boundary surfaces for both of F-string and D-string, we do not explicitly fix σ in our consideration.

3. D-branes from κ-invariance

Let us consider D-branes on the AdS$_5\times$S^5 by following the idea of Lambert and West [9]. They considered the Dp-branes from the κ-invariance of the Green-Schwarz type IIB string in flat space and obtained the standard fact that the value p is odd. Such a constraint comes from the requirement that we should impose appropriate boundary conditions in order to delete the surface terms coming from the κ-variation and to ensure the consistency of the theory.

The idea of Lambert and West can be applicable to non-trivial backgrounds, including the AdS$_5\times$S^5 and the pp-wave. In these cases, the boundary conditions restrict not only the value p but also the configuration of a Dp-brane, and lead to the classification of possible D-branes [7,8,10,11,18,19,20].

3.1. The classification of 1/2 SUSY D-branes on the AdS$_5\times S^5$

The classification of 1/2 SUSY D-branes on the AdS$_5\times$S^5 [10] was given by considering the vanishing conditions of the κ-variation surface terms up to and including the fourth order in θ. This result is still valid even at full order of θ [11]. The result is as follows: For the $d = 2$ (mod 4) case, where d is the number of Dirichlet directions, the possible configurations of D-branes need to satisfy the condition:

- The number of Dirichlet directions in the AdS_5 coordinates $(X^0, \cdots, X^4)$ is even, and the same condition is also satisfied for the S^5 coordinates $(X^5, \cdots, X^9)$.

For the $d = 4$ (mod 4) case, D-branes satisfying the following condition are allowed:

- The number of Dirichlet directions in the AdS_5 coordinates $(X^0, \cdots, X^4)$ is odd, and the same condition is also satisfied for the S^5 coordinates $(X^5, \cdots, X^9)$.

For a D-brane on the $\mathrm{AdS}_5 \times \mathrm{S}^5$, the directions to which the brane world-volume can extend are restricted. All the possible D-brane configurations at the origin are summarized in Tab. 1. When we consider the D-branes sitting outside the origin, only a D-instanton is allowed as a 1/2 SUSY object.

Table 1: The possible 1/2 SUSY D-branes of F (D)-string on the $\mathrm{AdS}_5 \times \mathrm{S}^5$, sitting at the origin.

D-instanton	D (F)-string	D3-brane	D5 (NS5)-brane	D7	D9 (NS9)-brane
(0,0)	(0,2), (2,0)	(1,3), (3,1)	(2,4), (4,2)	(3,5), (5,3)	absent

3.2. Penrose Limit of D-branes on the $AdS_5 \times S^5$

The Penrose limit [13] of the $\mathrm{AdS}_5 \times \mathrm{S}^5$ background leads to the maximally supersymmetric pp-wave background [14]. We may consider the Penrose limit of our classification result presented in the previous subsection. Then we can classify the possible D-branes on the pp-wave, including the well-known results in the light-cone analysis of the pp-wave string [3,4,6] (For the detail, see our work [10]). The result is summarized in Tab. 2, which reveals the AdS origin of D-branes on the pp-wave. It is also consistent with the brane probe analysis [5]. Notably, we can see why 1/2 SUSY D-strings do not appear in the light-cone analysis.

Table 2: Penrose limit of D-branes on the $\mathrm{AdS}_5 \times \mathrm{S}^5$.

D7-brane			
$(3,5)$		$(5,3)$	
$D^2 \swarrow$	$\searrow N^2$	$D^2 \swarrow$	$\searrow N^2$
$-$	$(+,-;2,4)$	$-$	$(+,-;4,2)$

D5 (NS5)-brane			
$(2,4)$		$(4,2)$	
$D^2 \swarrow$	$\searrow N^2$	$D^2 \swarrow$	$\searrow N^2$
$(2,4)$	$(+,-;1,3)$	$(4,2)$	$(+,-;3,1)$

D3-brane			
$(1,3)$		$(3,1)$	
$D^2 \swarrow$	$\searrow N^2$	$D^2 \swarrow$	$\searrow N^2$
$(1,3)$	$(+,-;0,2)$	$(3,1)$	$(+,-;2,0)$

D (F)-string			
$(0,2)$		$(2,0)$	
$D^2 \swarrow$	$\searrow N^2$	$D^2 \swarrow$	$\searrow N^2$
$(0,2)$	$-$	$(2,0)$	$-$

$-$:We cannot take this boundary condition.

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